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Technical Lesson 36

PRACTICAL RADIO CONSTRUCTION

We now come to the subject of tuned radio-frequency amplification - a system of reception employed in practically all present day types of broadcast receivers.

Radio-frequency amplification, when properly designed and constructed, serves to increase the sensitivity of a receiver and also increases the volume of the received signals. It might be well to mention here that the same may be said of audio-frequency amplification; but the difference between the two lies in which of these two qualities predominate in the system of amplification being considered. The object in using audio-frequency amplification is to secure great volume of signal; that it aids somewhat in increasing the range over which signals may be heard is incidental. On the other hand, the principle reason for using radio-frequency amplification is that by its use signals from greater distances can be received and which would otherwise be inaudible; while its ability to increase the volume of received signals is a factor subservient to its distance-getting ability.

Furthermore, tuned radio-frequency amplification (often abbreviated "tuned RF" amplification, or "TRF" amplification) when properly designed and constructed, increases the over-all selectivity of the receiver due to the number of tuned circuits which must necessarily be employed.

At practically all times the receiving antenna is intercepting signals from distant transmitting stations which are so weak that they are incapable of producing an appreciable response in the detector tube, and therefore, even though a powerful audio-frequency amplifier is being used, these weak signals cannot be heard; for it goes without saying that before an audio-frequency amplifier can amplify a signal, that signal must first cause an appreciable response in the detector tube. Should the signal be so weak that it is incapable of operating the detector tube, the audio-frequency amplifier will be of no use as an aid to reception for it cannot be expected to amplify impulses that it does not get.

Vacuum tubes are therefore used to amplify the signal at its original radio-frequency before it is required to operate the detector and, when so used, these tubes are termed radio-frequency amplifying tubes. By their use, signals too weak to otherwise satisfactorily operate the detector tube are amplified in strength to the point where they will produce in the detector tube a signal strong enough for the audio-frequency amplifier to take hold of and then, by amplification at audio-frequency, the signal is increased to loud speaker proportions.

Radio-frequency amplifiers may incorporate as many stages of amplification as the designer or constructor wishes to employ, or rather, as many as he can use successfully; for when too many stages are used complications develop that limit the number of stages that can be put to practical usage. The great majority of modern radio broadcast receivers in use today employ from one to three stages of tuned radio-frequency amplification although there are a comparative few which incorporate four and even five stages. In general, it may be said that two stages is the usual number found in a receiver designed to operate with an ordinary outdoor antenna, while three stages is considered to be the practical limit when the receiver is intended for use with a loop antenna or a small indoor antenna.

Tuned radio-frequency amplification is very desirable in a receiver, but like all good things, there is "a string tied to it". This bug-bear of tuned radio-frequency amplification is oscillation in the RF amplifier tubes and this lesson serves to point out the cause of such oscillation, while subsequent lessons will deal with approved methods of overcoming this undesirable obstacle.

Oscillation in a radio-frequency amplifier is undesirable for the self-same reason that it is unwanted in a regenerative detector, i.e., when oscillation occurs in a radio-frequency amplifier the oscillations thus being generated by the RF amplifying tube combine with the incoming signal oscillations in much the same manner as in an oscillating detector tube, and the result is the shrill, whistling squeal of the resultant beat, or heterodyne, frequency thus formed. Therefore, it is important to suppress oscillation in a radio-frequency amplifier for, if it occurs, the receiver becomes useless as a medium for the enjoyment of radio broadcast entertainment.

The cause of oscillation in a radio-frequency amplifier can be summed up in one word - "feed-back". It makes no difference whether such feed-back takes place through electro-magnetic coupling or electro-static coupling; if feed-back exists to an appreciable degree and is of proper phase (and it usually is), oscillation will take place.

In Figure 1 is shown the schematic wiring diagram of a receiver incorporating one stage of tuned radio-frequency amplification and a vacuum tube detector. To this circuit may or may not be added an audio-frequency amplifier, according to the choice of the constructor. The "picture" diagram of Figure 2 indicates the placement of apparatus and wiring, and it also shows two stages of transformer-coupled audio-frequency amplification as already described in a preceding lesson (No. 29). Note especially the relative positions of the radio-frequency transformer, RFT₁, and the radio-frequency transformer, RFT₂, (three-circuit tuner). Heretofore we have been referring to that piece of apparatus indicated as RFT₂ as a "three-circuit tuner", as that is the name that is popularly ascribed to it in the broadcast reception field. More specifically, it is a radio-frequency transformer and the principle difference between it and the radio-frequency transformer indicated at RFT₁ is that it is equipped with a coil that can be used as a tickler.

It would be well to mention now that the requirements necessary to produce oscillation in a detector tube apply equally well to radio-frequency amplifying tubes. It makes no difference whether a vacuum tube is being operated as a detector or as a radio-frequency amplifier, the circumstances which will produce oscillation in the tube remain the same in each instance.

With the foregoing fact in mind take note of the similarity existing between Figure 1 of this lesson and the wiring diagram of Figure 2 in Lesson 34. The principle difference is that the tube whose grid circuit is coupled to the antenna is now operating as a radio-frequency amplifier instead of as a detector; but, as in Lesson 34, its plate circuit is inductively coupled to a tuned circuit, L_2C_2 . The one remaining point of difference is that this same tuned circuit, L_2C_2 , is now connected to the input (grid) circuit of another vacuum tube which is operating as a detector. Aside from these two minor points of difference, a brief comparison should reveal that, from the antenna up to and including L_2C_2 , the circuit of this lesson is markedly similar to that of Lesson 34.

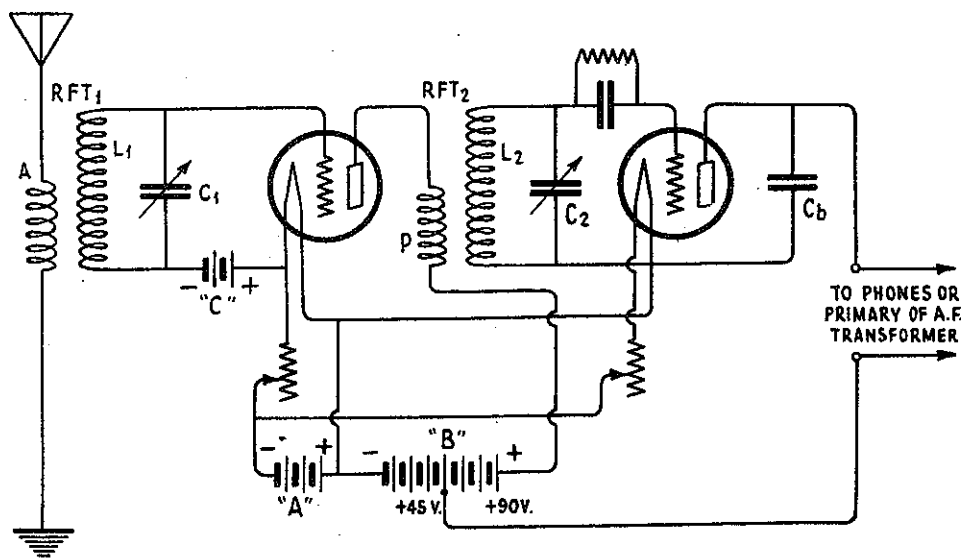


Figure 1

Let us now consider what occurs when a passing electro-magnetic wave radiated from a distant transmitter is intercepted by the receiving antenna. When a wave from a distant transmitter is intercepted by the antenna a radio-frequency current, identical in its characteristics with that of the passing wave, will be induced in the antenna circuit. Connected in series with the antenna circuit is the primary, A, of the radio-frequency transformer, RFT₁, whose secondary, L₁, is connected to the input terminals of the RF amplifier tube. Thus, when current flows in the antenna circuit voltage is induced in the secondary, L₁, and this voltage is applied to the grid of the RF amplifier tube. In order to effect the maximum possible transfer of energy from the antenna circuit to the grid circuit of the RF amplifier tube it is

necessary that the secondary, L_1 , be tuned to resonance with the radio-frequency current flowing in the primary, A . This is accomplished by adjustment of condenser, C_1 , which, in conjunction with L_1 , enables the user to tune the grid circuit of the RF amplifier tube to any wavelength in the broadcast band of 200 to 550 meters; and when the secondary circuit, L_1C_1 , of RFT_1 is thus resonated to the frequency of the incoming signal, maximum transfer of energy from the antenna circuit to the grid circuit of the RF amplifier tube is secured with consequent maximum response from the tube. These radio-frequency potentials being impressed upon the grid of the tube by the incoming signal cause corresponding fluctuations of the plate current. These radio-frequency fluctuations of the plate current are termed, as you know, the radio-frequency component of the plate current and, furthermore, is the same in its characteristics as the signal frequency actuating the grid except that it is considerably strengthened due to the amplifying ability of the tube.

The plate circuit of the RF amplifier tube includes the primary, P , of the radio-frequency transformer RFT_2 ; the secondary, L_2 , being connected to the input terminals of the detector tube. In this manner the grid circuit of the detector tube is coupled to the plate circuit of the RF amplifier tube. In order that the maximum possible transfer of energy can take place from the plate circuit of the RF tube to the grid circuit of the detector it is necessary to resonate the secondary, L_2 , to the frequency of the radio-frequency current flowing through the primary, P . This is accomplished by adjustment of the variable condenser, C_2 and, when resonance is thus secured, the amplified signal energy in the plate circuit of the RF amplifier tube is transferred to the grid circuit of the detector tube with maximum effectiveness.

The primary, P , of the radio-frequency transformer, RFT_1 , can be rotated in order that the degree of coupling between primary and secondary can be varied at will. Thus, when the primary is set at right angles to the secondary the coupling between them is reduced to minimum. The transfer of energy from primary to secondary is then very small, viz., the amount of signal energy transferred to the grid circuit of the detector tube is very slight and, of course, the received signal will be weak or even inaudible.

Rotating the primary, P , so that it becomes more nearly parallel to the secondary, L_2 , increases the coupling between the two circuits involved and an increase in the transfer of energy from the plate circuit of the RF amplifier tube to the grid circuit of the detector tube is secured. This increased transfer of energy results in greater signal strength and this increase in signal strength will continue with increases in coupling until an optimum value of coupling is secured at which the signal is strongest.

However, before the degree of coupling which will give maximum signal strength is reached the RF amplifier tube will begin to oscillate.

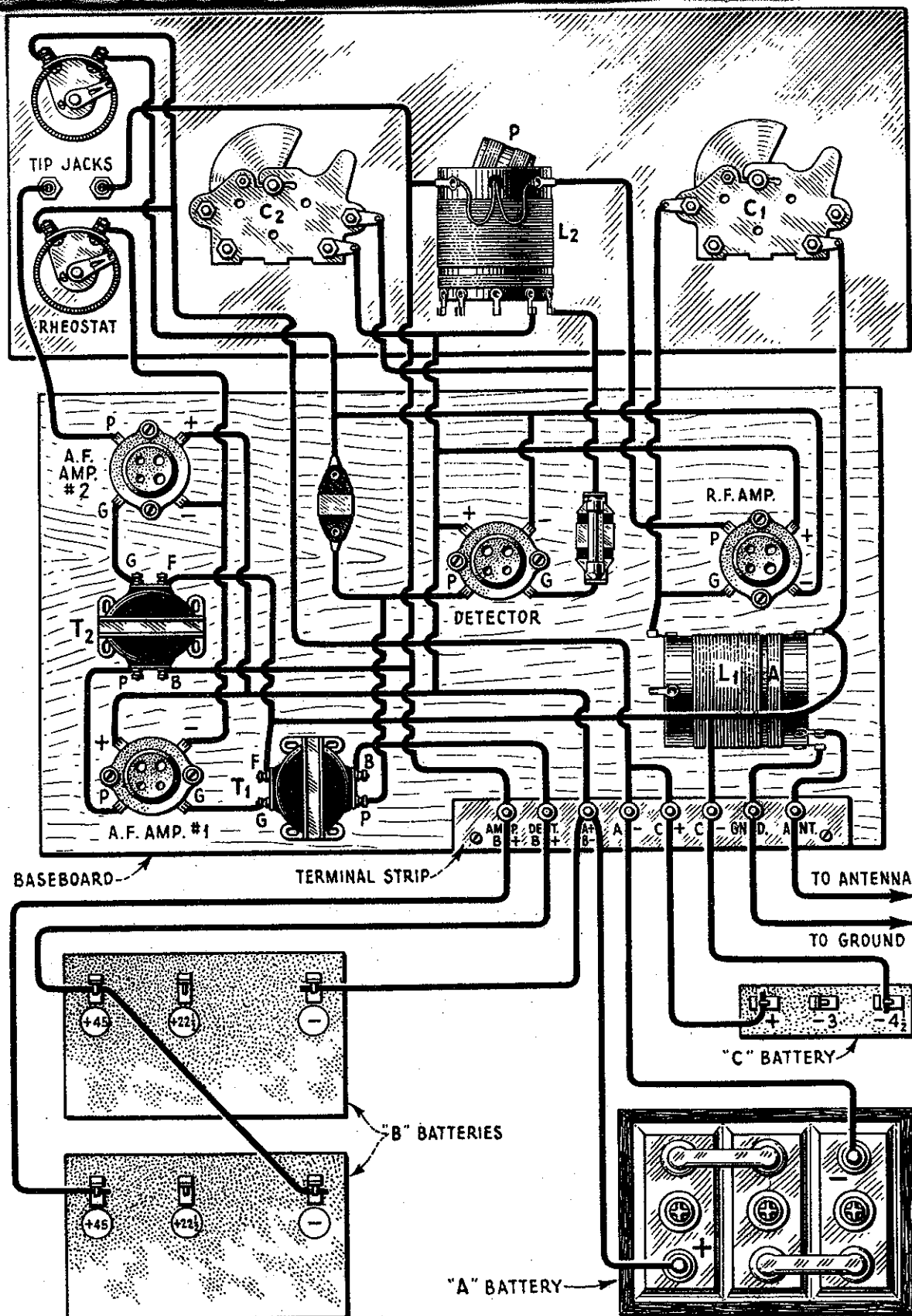


Figure 2. This is the circuit shown in Figure 1 to which two stages of AF amplification has been added.

This is quite as it should be in view of certain considerations with which we have already dealt in Lesson 34.

To again enter into these same considerations in detail; it will be noted that in order for the signal to be transferred from the primary, P, to the secondary, L₂, of the radio-frequency transformer, RFT₂, it is necessary that the secondary of this transformer be tuned to resonance with the incoming signal. This automatically brings this circuit, L₂C₂, into resonance with circuit, L₁C₁, inasmuch as both are, of course, tuned to the same signal. That is, if the incoming signal is of a wavelength of say, 300 meters, both circuit, L₁C₁, and circuit, L₂C₂, must be tuned to 300 meters in order that the signal can be received.

Do not overlook the fact that the tuned circuit, L₁C₁, is connected in the grid circuit of the RF amplifier tube, and that a similarly tuned circuit, L₂C₂, is coupled to the plate circuit of the same tube.

From the foregoing it can be readily appreciated that the same conditions that gave rise to oscillations in the detector tube circuit of Lesson 34 are present also in this circuit insofar as the RF amplifier tube is concerned. That is to say, both the grid and plate circuits of the tube are tuned to resonance with the same wavelength and the result is feed-back through the plate-grid capacity of the tube with consequent oscillation therein.

Furthermore, oscillation in the RF amplifier tube of this circuit can be controlled exactly as in Lesson 34, i.e., by adjustment of the coupling between the plate circuit and the tuned circuit, L₂C₂; thus, oscillation in the RF amplifier tube can be stopped by reducing the coupling between the plate coil, P, and the tuned circuit L₂C₂. However, reducing the coupling between coils P and L₂ will also decrease the transfer of energy from the plate circuit of the RF amplifier tube to the grid circuit of the detector tube, and this is undesirable for the strength of received signals is reduced as this coupling is decreased. Therefore, if we use sufficiently tight coupling between coils P and L₂ to secure good transfer of energy the RF amplifier tube will oscillate; on the other hand, if the coupling is reduced sufficiently to stop oscillation the transfer of energy from the plate circuit of the RF amplifier tube to the grid circuit of the detector tube is lessened with a consequent depreciation in signal strength.

However, if care is exercised in the adjustment of the coupling between coils P and L₂ so that the RF amplifier tube just ceases to oscillate it then becomes regenerative, and this regeneration will often more than compensate for the decrease in signal strength that would otherwise take place. Yet this degree of coupling that enables us to derive the benefits of regeneration is critical in its adjustment and, moreover, it varies with each change in the tuning of the circuit. Each time the wavelength adjustments of the receiver are changed as the receiver is tuned from one station to another,

the coupling between coils P and L₂ must be re-adjusted in order to maintain the RF amplifier tube at this critical point at which it does not oscillate yet, preferably, is regenerative.

The wavelength to which the tuned circuits L₁C₁, and L₂C₂, are tuned will determine to a great extent the amount of coupling necessary between coils P and L₂. This relationship between wavelength and coupling evidences itself in practice as follows: The shorter the wavelength to which the receiver is tuned the looser must be the coupling in order to avoid oscillation; and, conversely, the longer the wavelength to which the receiver is tuned the closer the coupling can be without oscillation.

Begin the construction of this receiver by first wiring in the filament circuit. This is done in such a way that the filament current supplied to both the RF amplifier tube and the detector tube is controlled by one rheostat, and the remaining rheostat is used to control the filament current of the two AF amplifier tubes. Run a wire from the negative "A" binding post on the terminal strip to one terminal of a rheostat. The other terminal of this rheostat is connected to the negative (-) filament terminals on both the RF amplifier and detector tube sockets. Now connect the positive "A" binding post on the terminal strip to both the positive (+) filament terminals of these same two tube sockets. The primary (small 10-turn coil) of the radio frequency transformer should now be connected to the antenna and ground binding posts on the terminal strip. The secondary coil of this transformer is connected into the circuit as follows: The end of the secondary winding that is nearest the primary winding (the "low" end of the secondary) is connected to the rotor plates of the tuning condenser, C₁, and also to the negative "C" binding post on the terminal strip. The "high" end of the secondary (the end of the secondary furthest from the primary) is now connected to the grid terminal of the RF amplifier tube socket and also to the stator plates of condenser, C₁. The plate terminal of this socket is connected to one terminal of the movable coil of the radio-frequency transformer, RFT₂ (the three-circuit tuner). The remaining terminal of this coil is connected to the B+amp binding post on the terminal strip. This movable coil is the same one that, in preceding hook-ups, functioned as a tickler coil; but when connected in accordance with the above directions it becomes the primary coil of the radio-frequency transformer, RFT₂.

The "low" end of this transformer's secondary (the end of the winding nearest the movable primary coil) is connected to the rotor plates of the tuning condenser, C₂, and also to the positive side of the filament circuit. The "high" end of the secondary winding should then be connected to the stator plates of the tuning condenser, C₂, and also to one terminal of the grid condenser. (Note: The small fixed winding on the "three-circuit" tuner is not used in the hook-up of this lesson.) The remaining terminal of the grid condenser should then be connected to the grid terminal of the detector tube socket; and the grid leak clipped into place only after the soldering of these grid condenser connections has been finished. The plate

terminal of the detector tube socket is now connected to the "p" terminal of the first-stage AF transformer; and to this same terminal is connected a terminal of the by-pass condenser, Cb, (marked 0.001 mfd.). The other terminal of this condenser is connected to the negative side of the filament circuit. The "B" terminal of the first-stage transformer should now be connected to the B+amp binding post on the terminal strip. The connections of the audio-frequency amplifier have already been covered in detail in Lesson 29.

After connecting the receiver to the antenna, ground and batteries it is ready to be put into operation. Before tuning for stations place the movable primary coil "P" of the radio-frequency transformer, RFT₂, in the position of maximum coupling, i.e., place it parallel to the secondary winding, L₂. Now tune in a station by adjusting the two tuning condensers. When a station has been tuned in it will probably be found that the RF amplifier tube is oscillating. Such oscillation can be stopped by lessening the coupling between the coils P and L₂ and this coupling should be decreased until the RF amplifier tube just stops oscillating and thereby becomes regenerative

Follow this procedure while tuning in a number of stations of different wavelengths throughout the broadcast band between 200 and 300 meters. While doing this take note of the value of coupling necessary to adjust the RF amplifier tube to the point where it does not quite oscillate. It will be found that as the wavelength of the received stations becomes shorter this critical degree of coupling becomes less.

Do not fail to take note that, if the coupling which gives best results when the receiver is tuned to a long wave station is used, when the tuning of the receiver has been changed in order to receive a station on a shorter wavelength, the RF amplifier tube will oscillate. On the other hand, if a long wave station is tuned in and the coupling is left at the value which gave best results on a shorter wavelength, it will be found that the received signals will not be as strong as when the coupling is increased to the proper amount.

When making the foregoing comparisons between short and long wavelength receiver adjustments to determine their relationship to the coupling of coil, P, to coil, L₂, it would be well to make them between a station transmitting on a wavelength of about 200 meters and a station transmitting on a wavelength of about 400 or 450 meters. There will then be a pronounced difference between the values of coupling which give the best results at the two different wavelengths.

EXAMINATION - LESSON 36.

1. Why is radio-frequency amplification used?
2. Why is oscillation in the radio-frequency amplifier undesirable?
3. What is the purpose of radio-frequency transformer RFT₂?
4. What is the cause of oscillation in a radio-frequency amplifier?
5. What kind of coupling is employed in RFT₁ and RFT₂?
6. Does increasing the coupling between coils P and L₂ increase the liability of oscillation in the RF amplifier tube?
7. Will the same circumstances that cause oscillation in a detector tube cause oscillation in a radio-frequency amplifier tube?
8. Is the detector tube, shown in Figure 1, regenerative or non-regenerative? Why?
9. If the RF amplifier tube were oscillating, what would you do to stop it?
10. How would you adjust coil P in order to secure maximum signal strength?